9/582982

534 Rec'd PCT/PTC 10 JUL 2000

SPECIFICATION

Antifriction Bearing Part for High Temperature

Technical Field

The present invention relates to an antifriction bearing part employed for a power transmission device or an engine part of an automobile, an aircraft, a ship or an industrial machine, and more specifically, it relates to a low-priced antifriction bearing part for a high temperature having an excellent rolling contact fatigue life also under environment contaminated with foreign matter such as dust or refuse and under such environment that the temperature of the atmosphere is room temperature to 300°C.

Background Art

An antifriction bearing employed for a power transmission part or an engine part of an automobile, an aircraft, a ship or an industrial machine, which comes to be used under severe environment, is required to have an excellent rolling contact fatigue life and reliability also under such environment. In particular, the antifriction bearing employed for the above may be contaminated with foreign matter such as dust, refuse or iron powder and, it is known that the rolling contact fatigue life remarkably lowers under such environment as compared with employment under clean environment. As a countermeasure therefor, a working method of performing carbonitriding on high-carbon chromium bearing steel such as SUJ2 or case-hardening steel such as SCM420, SNCM420 or SNCM815 and generating a proper amount of retained austenite immediately under a rolling surface is recently applied and life improvement under contamination with foreign matter is attempted.

However, general carbonitriding is treatment of a longer time as compared with quench-and-temper treatment applied to SUJ2 steel or the like. In such a carbonitrided antifriction bearing, therefore, there is such a problem that the manufacturing cost remarkably increases as compared

with an antifriction bearing manufactured in a general quench-and-temper step.

Further, the antifriction bearing employed for an automobile or an aircraft is used under high-temperature environment and hence required to have an excellent rolling contact fatigue life characteristic under extremely severe working environment that is environment contaminated with foreign matter and high-temperature environment. In general, tempering is executed on an antifriction bearing used under a high temperature at a high temperature of at least 300°C for attaining dimensional stability after performing quench hardening on a high-carbon chromium bearing of SUJ2 or the like or after performing cementation/quench hardening on case-hardening steel such as SCM420 or SNCM815.

However, hardness remarkably lowers when tempering these materials at a high temperature and hence prescribed hardness required to the antifriction bearing cannot be attained but the rolling contact fatigue life and wear resistance lower. Therefore, a precipitation-hardening type steel product such as M50 is used for bearing steel used in a high-temperature range, while it has been impossible for such a steel product to satisfy the aforementioned needs since the manufacturing cost and the material cost are high and the working temperature range is limited.

In the antifriction bearing subjected to carbonitriding, retained austenite is generated immediately under a rolling surface after heat treatment while nitrogen infiltrates into the steel. Stress concentration resulting from contamination with foreign matter is relaxed due to the function of this retained austenite while temper softening resistance is improved due to the function of nitrogen entering into the steel and change of the structure caused in the process of rolling contact fatigue is suppressed, whereby improvement of the rolling contact fatigue life is attained.

In application to an antifriction bearing for a high temperature, however, high-temperature tempering must be performed for ensuring stability of the dimensions as described above. When performing this high-temperature tempering, the effect cannot be expected since the

retained austenite decomposes and the quantity thereof decreases while temper softening prevention by nitrogen is also limited and hence sufficient performance cannot be attained under high-temperature environment contaminated with foreign matter.

While high output·miniaturization of an engine recently rapidly progresses in the field of an automobile or the like, a case used under severer conditions increases at the same time as to the working environment for the antifriction bearing. It is expected that the working temperature range, which is about 130°C at room temperature, of an antifriction bearing employed for an engine part instantaneously temperature-rises up to 160°C. It is predicted nowadays that the working temperature range of the antifriction bearing rises to about 160°C at room temperature and further instantaneously exceeds 200°C following increase of the output of the engine. Therefore, it is expected that, when increase of the output or reduction of the weight of the engine is hereafter prompted, improvement of the rolling contact fatigue life under environment contaminated with foreign matter and under high-temperature environment is required.

However, the current high-carbon chromium bearing steel or an antifriction bearing subjected to cementation or carbonitriding does not have sufficient heat resistance and cannot maintain a sufficient rolling contact fatigue life under the expected environment contaminated with foreign matter and under the high-temperature environment. Further, the precipitation-hardening type bearing steel such as M50 has such a problem that the cost is high, and the situation is that an antifriction bearing low-priced and excellent in rolling contact fatigue life characteristic cannot be provided.

The present invention has been proposed in order to solve the aforementioned problems, and aims at providing an antifriction bearing part for a high temperature having an excellent rolling contact fatigue life also under environment contaminated with foreign matter and under high-temperature environment and low-priced as compared with the prior art.

Disclosure of the Invention

The inventors have made deep study to find out a combination of composition elements capable of obtaining a low-priced antifriction bearing part for a high temperature having an excellent rolling contact fatigue life under environment contaminated with foreign matter and under high-temperature environment and each content thereof.

Accordingly, an antifriction bearing part for a high temperature according to the present invention is a part of an antifriction bearing for a temperature having an inner ring, an outer ring and a rolling element, which consists of a steel product containing C (carbon) by at least 0.6 % and not more than 1.3 %, Si (silicon) by at least 0.3 % and not more than 3.0 %, Mn (manganese) by at least 0.2 % and not more than 1.5 %, P (phosphorus) by not more than 0.03 %, S (sulfur) by not more than 0.03 %, Cr (chromium) by at least 0.3 % and not more than 5.0 %, Ni (nickel) by at least 0.1 % and not more than 3.0 %, Al (aluminum) by not more than 0.050 %, Ti (titanium) by not more than 0.003 %, O (oxygen) by not more than 0.0015 % and N (nitrogen) by not more than 0.015% in mass % as the contents of alloying elements with the rest consisting of Fe (iron) and unavoidable impurities and has a structure subjected to tempering after quench hardening or carbonitriding, while the hardness after the tempering is at least HRC 58 and the maximum carbide size is not more than 8 μm.

In the antifriction bearing part according to the present invention, an excellent rolling contact fatigue life is attained under environment contaminated with foreign matter when subjected to quench-and-temper treatment also when not subjected to carbonitriding since the same has the aforementioned structure. Therefore, carbonitriding can be omitted and hence the manufacturing cost can be lowered.

While it is preferable to omit carbonitriding in view of reduction of the manufacturing cost as described above, an excellent rolling contact fatigue life can be attained under environment contaminated with foreign matter also when performing carbonitriding in place of quench hardening.

Further, it has the aforementioned composition and hence high hardness of at least HRC 58 can be attained also when subjected to

tempering at a high temperature (e.g., 350°C). The quantity of retained austenite can be reduced by thus performing tempering at a high temperature, whereby dimensional stability under high-temperature environment can be attained while high hardness of at least HRC 58 can be attained. Therefore, the rolling contact fatigue life and wear resistance under high-temperature environment can be improved beyond the prior art.

Further, the steel of the aforementioned composition is more low-priced than the precipitation-hardening type bearing steel such as M50.

Thus, it is possible to obtain an antifriction bearing part for a high temperature, which has an excellent rolling contact fatigue life under environment contaminated with foreign matter and under high-temperature environment and is at a low cost.

The tempering temperature is preferably at least 180°C and not more than 350°C. The antifriction bearing is generally used at a temperature of about 100°C, and hence the tempering temperature must be at least 180°C.

The reasons for limiting the chemical compositions of the antifriction bearing part for a high temperature according to the present invention are now described.

(1) As to the content (at least 0.6 % and not more than 1.3 %) of C

C is an element essential for ensuring strength as the antifriction bearing and must be contained by at least 0.6 % in order to maintain prescribed hardness after heat treatment, and hence the lower limit of the C content has been limited to 0.6 %. While a carbide provides an important role for the rolling contact fatigue life in the present invention as described later, it has been proved that a large-sized carbide forms and causes reduction of the rolling contact fatigue life when C is contained in excess of 1.3 % in content, and hence the upper limit of the C content has been limited to 1.3 %.

(2) As to the content (at least 0.3 % and not more than 3.0 %) of Si

Si has a function of suppressing softening in a high temperature range and improving heat resistance of the antifriction bearing and is hence preferably added. However, these effects cannot be attained if the Si

content is less than 0.3 %, and hence the lower limit of the Si content has been limited to 0.3 %. While the heat resistance improves following increase of the Si content, the effect is saturated and reduction of hot workability and machinability takes place when Si is contained in a large quantity exceeding 3.0 % and hence the upper limit of the Si content has been limited to 3.0 %.

(3) As to the content (at least 0.2 % and not more than 1.5 %) of Mn

Mn is an element employed for deoxidization when preparing steel and an element improving quench-hardenability and must be added by at least 0.2 % for attaining this effect, and hence the lower limit of the Mn content has been limited to 0.2 %. However, the machinability remarkably lowers when Mn is contained in a large quantity exceeding 1.5 %, and hence the upper limit of the Mn content has been limited to 1.5 %.

(4) As to the content (not more than 0.03 %) of P

P segregates on austenite grain boundaries of the steel and causes reduction of toughness and the rolling contact fatigue life, and hence 0.03 % has been set as the limit of the content.

(5) As to the content (not more than 0.03 %) of S

S harms hot workability of the steel, forms a non-metallic inclusion in the steel and lowers the toughness and the rolling contact fatigue life, and hence 0.03 % has been set as the upper limit of the S content. S has an effect of improving machinability while having the aforementioned harmful side, and hence a content of up to 0.005 % is allowed although the content is desirably reduced to the smallest possible level.

(6) As to the content (at least 0.3 % and not more than 5.0 %) of Cr

Cr is an element accomplishing an important function in the present invention, and added for improvement of quench-hardenability, assurance of hardness by a carbide and life improvement. Addition of at least 0.3 % is necessary for obtaining a prescribed carbide, and hence the lower limit of the Cr content has been limited to 0.3 %. However, a large-sized carbide forms to result in reduction of the rolling contact fatigue life when Cr is contained in a large quantity exceeding 5.0 %, and hence the upper limit of the Cr content has been limited to 5.0 %.

(7) As to the content (not more than 0.050 %) of Al

While Al is used as a deoxidant when preparing steel, it is desirable to reduce the content since Al forms a hard oxide inclusion and lowers the rolling contact fatigue life. Remarkable reduction of the rolling contact fatigue life was recognized when Al was contained in a large quantity exceeding 0.050 %, and hence the upper limit of the Cr content has been limited to 0.050 %.

Increase of the preparation cost for steel takes place for rendering the Al content less than 0.005 %, and hence it is preferable to limit the lower limit of the Al content to 0.005 %.

(8) As to the content (not more than 0.003 %) of Ti, the content (not more than 0.0015%) of O and the content (not more than 0.015 %) of N

Ti, O and N form oxides and nitrides in the steel, become starting points of fatigue failure as non-metallic inclusions and lower the rolling contact fatigue life, and hence Ti: 0.003 %, O: 0.0015 % and N: 0.015 % have been set as the upper limits of the respective elements.

(9) As to the content (at least 0.1 % and not more than 3.0 %) of Ni

Ni is an element accomplishing an important function in the present invention, suppresses change of the structure in a rolling contact fatigue process particularly when used under high-temperature environment, and has an effect of suppressing reduction of the hardness in a high temperature range and improving the rolling contact fatigue life. In addition, Ni improves the toughness for improving the life under foreign matter environment and has an effect also for improvement of corrosion resistance. Therefore, Ni must be contained by at least 0.1 %, and hence the lower limit of the Ni content has been limited to 0.1 %. When containing Ni in a large quantity exceeding 3.0 %, however, a large quantity of retained austenite is formed in quench hardening and prescribed hardness cannot be attained while the steel product cost rises, and hence the upper limit of the Ni content has been limited to 3.0 %.

Temper hardness of the inventive antifriction bearing part for a high temperature and the carbides are now mentioned.

(10) Temper Hardness

It is general that a bearing used in a high temperature range is subjected to tempering at a temperature exceeding the environmental temperature in order to stabilize the dimensions under the working environment. The inventors have made detailed investigations related to the temper hardness and the rolling contact fatigue life under temperature environment of 200°C, to confirm that correlation is recognized between the temper hardness and the rolling contact fatigue life and the rolling contact fatigue life tends to exhibit a longer life as the temper hardness is high. I has been found out that, particularly when the temper hardness is identical, a bearing for which tempering is executed at a high temperature has a longer life and a bearing whose temper hardness is high has a longer life also when performing tempering at a high temperature. Further, it has been proved that the life tends to abruptly lower and life dispersion increases when the hardness after tempering is less than HRC 58. In order to improve the life at a high temperature and reduce dispersion, it is necessary to maintain hardness of at least HRC 58, and the tempering temperature at this time is preferably as high as possible.

(11) Carbides

It has been proved that the carbides make the hardness in tempering maintained while suppressing structural change during rolling contact fatigue, and has an effect for improvement of the rolling contact fatigue life. As a result of investigating the maximum size of the carbides in a depth of 0.1 mm from the surface layer of the bearing and the rolling contact fatigue life at this time, such a tendency that the life lowers when a large-sized carbide is present has been recognized and it has been clarified that life reduction abruptly takes place when a large carbide whose maximum size exceeds 8 μm is present, and hence the maximum size of the carbides has been defined as 8 μm.

Preferably in the aforementioned antifriction bearing part, the steel product further contains at least one of at least 0.05 % and less than 0.25 % of Mo and at least 0.05 % and not more than 1.0 % of V in mass %.

Thus, the rolling contact fatigue life under environment contaminated with foreign matter and under high-temperature

environment can be further improved, and the hardness after tempering can be improved.

The reasons for limiting the aforementioned chemical compositions are now described.

(12) As to the content (at least 0.05 % and less than 0.25 %) of Mo

Mo improves quench-hardenability of the steel, and has an effect of preventing softening in tempering by being solidly dissolved in the carbides. In particular, Mo is added since a function of improving the rolling contact fatigue life in a high temperature range has been found out. However, the steel product cost rises while hardness does not lower but machinability remarkably deteriorates in softening for simplifying cutting when Mo is contained in a large quantity of at least 0.25 %, and hence the Mo content has been limited to less than 0.25 %. No effect is attained for carbide formation if the content of Mo is less than 0.05 %, and hence the lower limit of the Mo content has been limited to 0.05 %.

(13) As to the content (at least 0.05 % and not more than 1.0 %) of V

V has an effect of bonding with carbon and precipitating a fine carbide, prompting refinement of crystal grains and improving strength·toughness while exhibiting a function of improving heat resistance of the steel product by containing of V, suppressing softening after high-temperature tempering, improving the rolling contact fatigue life and reducing dispersion of the life. The content of V at which this effect is attained is at least 0.05 %, and hence the lower limit of the V content has been limited to 0.05 %. However, machinability and hot workability lower if V is contained in a large quantity exceeding 1.0 %, and hence the upper limit of the V content has been limited to 1.0 %.

Best Mode for Carrying Out the Invention

Examples of the present invention are now described.

Steel products having chemical compositions shown in Table 1 were dissolved by a vacuum induction furnace, cast into steel ingots of 150 kg in weight and thereafter heated/held at a temperature of 1200°C for three hours for executing hot forging, for manufacturing round bars of 50 mm in

diameter. The round bar materials were subjected to treatment of holding the same at 850°C for one hour as normalizing and thereafter air-cooling the same, and further subjected to softening of holding the same at 790°C for six hours, thereafter cooling the same at a cooling rate of 10°C/hour to 650°C and air cooling the same to the room temperature as softening for simplifying cutting, for making materials for various investigations.

Table 1

	Steel Type	No.	Chemical Composition (Mass %)												
			C	Si	Mn	P	S	Ni	Cr	Mo	V	Al	Ti	0	N
Inventive Example	A	1	0.81	2.01	0.50	0.018	0.020	0.53	1.49	–	–	0.021	0.0023	0.0010	0.009
	B	2	1.01	0.75	0.45	0.019	0.020	1.01	1.51	–	–	0.020	0.0023	0.0011	0.011
	C	3	0.80	2.51	0.44	0.017	0.022	0.55	1.48	–	–	0.022	0.0024	0.0013	0.010
	D	4	1.21	1.01	0.35	0.018	0.019	0.78	1.49	–	–	0.020	0.0025	0.0010	0.011
	E	5	1.05	1.51	0.40	0.019	0.017	2.01	1.50	–	–	0.021	0.0022	0.0009	0.008
	F	6	1.01	1.49	0.45	0.016	0.021	1.51	1.51	–	–	0.021	0.0023	0.0010	0.009
	G	7	1.20	1.01	0.25	0.018	0.020	0.79	1.50	0.24	–	0.021	0.0024	0.0011	0.011
	H	8	1.01	0.51	0.45	0.019	0.021	2.51	1.51	–	0.41	0.022	0.0025	0.0010	0.010
	I	9	1.00	0.52	0.46	0.020	0.020	1.51	1.52	–	0.85	0.021	0.0022	0.0009	0.011
	J	10	1.00	1.48	1.10	0.018	0.020	1.52	1.48	–	–	0.022	0.0023	0.0011	0.009
	K	11	1.21	1.00	0.45	0.019	0.019	2.51	2.51	–	–	0.020	0.0023	0.0012	0.010
	L	12	1.01	0.50	0.35	0.017	0.021	0.79	4.51	–	–	0.021	0.0025	0.0011	0.010
Comparative Example	M	13	1.01	0.25	0.50	0.020	0.020	0.02	1.50	–	–	0.020	0.0022	0.0009	0.009
	N	14	1.22	0.22	0.45	0.019	0.019	0.02	1.49	–	–	0.021	0.0023	0.0010	0.010
	O	15	1.00	1.51	0.45	0.018	0.019	0.03	1.48	–	–	0.021	0.0024	0.0011	0.011
	P	16	1.23	1.01	0.35	0.017	0.018	0.02	1.51	–	–	0.020	0.0023	0.0011	0.010
	Q	17	0.55	1.00	0.40	0.016	0.017	0.50	1.50	0.25	–	0.020	0.0022	0.0010	0.010
	R	18	1.55	1.01	0.35	0.017	0.018	1.00	1.50	–	0.40	0.022	0.0023	0.0011	0.009
	S	19	1.21	1.00	0.30	0.065	0.040	0.50	1.50	–	–	0.065	0.0522	0.0025	0.025
	T	20	1.20	1.01	2.65	0.018	0.020	1.50	1.45	–	–	0.021	0.0021	0.0010	0.011
	U	21	1.21	0.98	0.45	0.017	0.019	1.50	6.01	–	–	0.020	0.0021	0.0011	0.009
	V	22	1.10	0.55	0.15	0.017	0.020	1.00	0.22	0.01	0.02	0.003	0.0020	0.0010	0.009
	W	23	1.15	1.01	0.45	0.018	0.020	1.50	1.45	0.35	–	0.021	0.0022	0.0011	0.010
	X	24	1.15	1.00	0.40	0.019	0.021	2.00	1.40	–	2.01	0.022	0.0021	0.0010	0.010
	Y	25	1.21	4.01	0.55	0.019	0.019	1.00	1.40	–	–	0.020	0.0022	0.0010	0.009
	Z	26	1.20	0.55	0.45	0.018	0.018	4.23	1.35	–	–	0.019	0.0020	0.0009	0.010

<Hardness Investigation>

In order to measure temper hardness after quench hardening and temper hardness after carbonitriding, columnar test pieces of 20 mm in diameter and 100 mm in length were prepared from materials of 50 mm in diameter by machining.

Quench hardening was performed by performing heating with a salt furnace, performing soaking to 850°C for 30 minutes, and thereafter quench-hardening the test pieces into oil of 80°C. Thereafter tempering of performing heating identically with a salt furnace, holding the test pieces at 350°C for two hours and thereafter air-cooling the same was performed as tempering.

In carbonitriding, a gas atmosphere furnace used in general production steps was employed for setting a carbon potential to 1.0 to 1.2 % and the amount of addition of NH_3 to 5 to 10 % in an RX gas atmosphere for holding the test pieces at 850°C for 60 minutes, and thereafter the test pieces were quench-hardened into oil. Thereafter tempering of 120 minutes was performed at 350°C.

Discoidal test pieces of 10 mm in thickness were cut from central portions of the test pieces subjected to this quench-and-temper treatment or the test pieces subjected to tempering after carbonitriding and both surfaces were polished by wet polishing, for preparing test pieces for hardness measurement.

As to the hardness, a Rockwell hardness meter was used for performing hardness measurement on positions 2 mm deep from the surfaces in sections of the test pieces, and mean values of seven points were obtained as the temper hardness.

<Rolling Contact Fatigue Life Test>

In order to confirm the performance as the antifriction part, a fatigue test was made with a thrust rolling contact fatigue life tester and life evaluation of the respective materials was executed.

As to the test pieces employed for life evaluation, ring-shaped thrust rolling contact fatigue life test pieces of 47 mm in outer diameter, 29 mm in inner diameter and 7 mm in thickness were roughly worked from round bar

materials of 50 mm in diameter by machining.

Quench-and-temper treatment and carbonitriding were performed as heat treatment of the test pieces for which rough working was completed. As to the treatment, an experimental furnace used in general production steps was employed.

As to the quench-and-temper treatment, a gas atmosphere furnace was employed for holding the test pieces at 850°C for 30 minutes while controlling the carbon potential in an RX gas atmosphere so that neither decarbonization or cementation took place on the basis of the carbon content of each steel, and the test pieces were thereafter quench-hardened into oil. Thereafter tempering of 120 minutes was performed at 350°C.

For carbonitriding, heat treatment was performed under the same conditions as those for the aforementioned hardness test pieces.

After completion of the heat treatment, both surfaces of the test pieces were polished and finished into mirror surface states. In the test pieces subjected to carbonitriding, working margins in polishing were set to 0.1 mm on both surfaces.

The rolling contact fatigue life test was executed with a thrust rolling contact fatigue life tester. Table 2 shows the conditions of the test. The test was executed under room temperature environment and under 200°C environment, and the test was also performed under environment reproducing environment contaminated with foreign matter.

Table 2

Rolling Contact Fatigue Life Test Conditions

Tester	Thrust Rolling Contact Fatigue Life Tester
Contact Pressure	5.0GPa
Rotational Speed	2000rpm
Test Temperature	Room Temperature, 200℃
Lubrication	Turbo Oil
Quantity of Foreign Matter	0.4g/1000cc

For the fatigue test, 15 repetitive tests were made under the same

conditions for determining such a life that a cumulative damage probability in a Weibull probability reaches 10 % as the life of each material. Comparative example No. 13 in Table 2 is general-purpose SUJ2, and the life value of each material was described with a probability on the assumption that the life of this quench-and-temper treated material was 1.0.

<Carbides>

Thrust rolling contact fatigue life test pieces were used for measurement of the carbides present in the steel. In test pieces worked into the thrust rolling contact fatigue life test pieces by executing various types of heat treatment, ring cross sections were cut for preparing micro test pieces for structure observation. The test pieces were mirror-finished, and further corroded with a picral corrosion solution for performing observation of carbides. In the micro samples, observation of carbides in 0.1 mm depths from surface layers of rolling surfaces was executed with an optical microscope and maximum carbides in a visual area of 50 mm^2 were measured.

Results of the aforementioned 350°C temper hardness, rolling contact fatigue lives at room temperature and 200°C, rolling contact fatigue lives under foreign matter contamination conditions and maximum carbide sizes are shown in Table 3 as to inventive Examples and in Table 4 as to comparative examples.

Table 3

No.	Steel Type	Treatment		350°C Temper Hardness (HRC)	Maximum Carbide Size (μm)	Ratio of Room Temperature Rolling Contact Fatigue Life	Ratio of 200°C Rolling Contact Fatigue Life	Ratio of Foreign Matter Rolling Life	
								Room Temperature	200°C
1	A	HT	Inventive Example	58.8	2.5	3.2	4.0	3.6	4.3
		Carbonitriding		59.3	3.3	3.5	4.8	4.1	5.5
2	B	HT		59.4	3.5	4.5	6.9	4.8	7.3
		Carbonitriding		59.8	3.7	4.7	7.8	5.2	8.4
3	C	HT		58.8	2.5	3.1	5.1	3.4	5.3
		Carbonitriding		60.0	2.9	3.5	5.8	4.0	6.3
4	D	HT		60.5	2.6	10.1	14.0	10.4	14.2
		Carbonitriding		61.1	3.1	10.7	15.2	11.3	15.7
5	E	HT		59.9	3.3	5.1	8.1	5.4	8.3
		Carbonitriding		59.3	3.9	7.0	10.2	7.7	10.8
6	F	HT		60.0	3.2	6.1	9.5	6.3	9.8
		Carbonitriding		60.7	4.0	8.5	11.1	8.9	11.6
7	G	HT		60.7	3.5	7.3	11.1	7.7	11.4
		Carbonitriding		61.5	4.7	7.9	13.2	8.5	13.8
8	H	HT		59.8	2.7	4.0	7.6	4.3	7.9
		Carbonitriding		59.0	3.5	7.0	9.5	7.5	10.0
9	I	HT		59.5	3.2	4.5	8.7	4.9	9.1
		Carbonitriding		60.1	4.0	6.5	10.0	7.1	10.5
10	J	HT		59.6	4.2	5.2	9.1	5.4	9.3
		Carbonitriding		59.9	5.0	7.3	9.4	7.8	10.0
11	K	HT		60.5	6.1	9.4	13.5	9.7	13.8
		Carbonitriding		60.0	6.7	7.5	10.3	8.0	10.8
12	L	HT		59.8	6.8	6.4	9.6	6.7	9.8
		Carbonitriding		61.1	7.5	4.2	6.5	4.7	7.0

Table 4

No.	Steel Type	Treatment		350°C Temper Hardness (HRC)	Maximum Carbide Size (μm)	Ratio of Room Temperature Rolling Contact Fatigue Life	Ratio of 200°C Rolling Contact Fatigue Life	Ratio of Foreign Matter Rolling Life	
								Room Temperature	200°C
13	M	HT	Comparative Example	55.6	1.1	1.0	1.0	1.0	1.0
		Carbonitriding		57.2	2.8	1.8	1.4	2.0	1.7
14	N	HT		56.0	2.5	1.1	1.3	1.1	1.2
		Carbonitriding		57.3	4.2	1.9	1.7	2.2	1.9
15	O	HT		60.1	2.8	2.1	2.5	2.0	2.5
		Carbonitriding		60.3	4.3	2.2	2.8	2.6	3.1
16	P	HT		60.1	3.0	2.2	2.1	2.0	1.9
		Carbonitriding		60.8	4.2	3.0	2.8	3.3	3.2
17	Q	HT		53.0	2.5	0.4	0.7	0.3	0.6
		Carbonitriding		54.3	2.3	0.5	1.1	0.9	1.4
18	R	HT		54.2	6.5	1.6	1.4	1.9	1.5
		Carbonitriding		61.5	9.2	0.9	1.0	1.0	1.2
19	S	HT		59.4	4.4	1.4	2.0	1.4	1.7
		Carbonitriding		60.3	5.1	2.4	2.4	2.5	2.6
20	T	HT		59.4	7.7	1.9	1.5	1.9	1.3
		Carbonitriding		59.9	6.5	1.7	1.7	1.9	1.8
21	U	HT		62.5	17.0	1.4	1.1	1.2	0.9
		Carbonitriding		63.0	29.0	0.8	0.8	0.9	1.1
22	V	HT		56.5	3.8	0.7	0.3	0.4	0.6
		Carbonitriding		57.7	3.7	0.8	0.6	0.9	0.5
23	W	HT		59.4	3.0	1.3	1.5	1.1	1.3
		Carbonitriding		60.0	3.4	2.2	2.2	2.3	2.3
24	X	HT		61.5	2.4	2.0	2.5	1.9	2.1
		Carbonitriding		62.0	3.3	2.2	2.7	2.3	2.9
25	Y	HT		62.5	1.4	2.3	2.7	2.3	2.9
		Carbonitriding		62.6	2.7	2.3	2.9	2.7	3.0
26	Z	HT		62.4	1.5	2.4	2.6	2.3	2.8
		Carbonitriding		62.3	2.5	2.1	2.9	2.6	2.9

From the aforementioned results in Table 3 and Table 4, it has been proved that hardness becomes at least HRC 58 in inventive Examples having the composition range of the present invention also when performing tempering of 350°C. In inventive Examples, further, it has been proved that the rolling contact fatigue lives at room temperature and 200°C and rolling contact fatigue lives under foreign matter conditions rise as compared with comparative examples also when performing mere quench-and-temper treatment (HT). It has also been proved that excellent rolling contact fatigue lives are attained also when performing carbonitriding in place of quench hardening. In inventive Examples, further, it has been proved that the maximum sizes of the carbides in the 0.1 mm depths from the surface layers of the rolling surfaces become not more than 8.0 μm.

Examples disclosed this time are to be considered as illustrative and not restrictive in all points. The range of the present invention is shown not by the above description but by the scope of claim for patent, and it is intended that all modifications in the meaning and the range equivalent to the scope of claim for patent are included.

As hereinabove described, the inventors have found out the optimum composition elements and the contents thereof, whereby an excellent rolling contact fatigue life has been attained under foreign matter contamination conditions without performing carbonitriding while it has been possible to obtain a low-priced antifriction bearing part for a high temperature capable of attaining high hardness also when performing tempering at a high temperature (e.g., 350°C).

Industrial Availability

The present invention is advantageously applicable to an antifriction bearing part for a high temperature used under environment contaminated with foreign matter and under high-temperature environment.